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Effect of Supplementation of Monomix and/or Pharmacological Levels of Zinc Oxide on Growth Performance of Nursery Pigs

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Effect of Supplementation of Monomix and/or Pharmacological Levels of Zinc Oxide on Growth Performance of Nursery Pigs

Abstract

A total of 354 pigs (DNA; 200 × 400; initial BW = 13.0 lb) were used in a 35-d growth trial to evaluate the effects of a short and medium chain fatty acid product (Monomix, Quality Technology International, Inc., Elgin, IL) added alone or in combination with pharmacological levels of ZnO on nursery pig performance. Upon arrival to the nursery research facility, pigs were randomly assigned to pens (5 pigs per pen) and pens were allotted to 1 of 4 dietary treatments with 18 pens per treatment. Dietary treatments were arranged in a 2 × 2 factorial with main effects of added ZnO (0 vs. 3,000 ppm/2,000 ppm in phases 1 and 2, respectively) and Monomix (0 vs. 0.4% in phases 1, 2, and 3). Treatment diets were formulated in three dietary phases fed from d 0 to 7, 7 to 18, and 18 to 35 post-weaning and were formulated to be isocaloric. No ZnO × Monomix interactions ($P = 0.399$) were observed throughout the 35-d study. There was no evidence for differences for the pigs consuming diets with added Monomix, other than decreased feed intake ($P = 0.002$) and average daily gain (ADG; $P = 0.012$) from d 0 to 7, resulting in decreased body weight (BW) ($P = 0.015$) at d 7. From d 0 to 7 and 7 to 18, pigs fed diets with added ZnO had increased ADG ($P < 0.001$), average daily feed intake (ADFI), and BW, and improved feed efficiency (F/G). Overall from d 0 to 35, pigs fed diets with added ZnO in phases 1 and 2 had increased ($P < 0.05$) ADG, ADFI, and d 35 BW, with no evidence for differences in performance in pigs fed diets with Monomix. In summary, the addition of Monomix did not improve pig performance, whereas pharmacological levels of ZnO improved ADG and ADFI similarly to previous studies.

Keywords

nursery pig, short chain fatty acids, medium chain fatty acids, zinc oxide

Cover Page Footnote

Appreciation is expressed to Quality Technology International, Inc. (Elgin, IL) for their partial financial support of this trial.

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Effect of Supplementation of Monomix and/or Pharmacological Levels of Zinc Oxide on Growth Performance of Nursery Pigs[1]

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Summary

A total of 354 pigs (DNA; 200 × 400; initial BW = 13.0 lb) were used in a 35-d growth trial to evaluate the effects of a short and medium chain fatty acid product (Monomix, Quality Technology International, Inc., Elgin, IL) added alone or in combination with pharmacological levels of ZnO on nursery pig performance. Upon arrival to the nursery research facility, pigs were randomly assigned to pens (5 pigs per pen) and pens were allotted to 1 of 4 dietary treatments with 18 pens per treatment. Dietary treatments were arranged in a 2 × 2 factorial with main effects of added ZnO (0 vs. 3,000 ppm/2,000 ppm in phases 1 and 2, respectively) and Monomix (0 vs. 0.4% in phases 1, 2, and 3). Treatment diets were formulated in three dietary phases fed from d 0 to 7, 7 to 18, and 18 to 35 post-weaning and were formulated to be isocaloric. No ZnO × Monomix interactions ($P = 0.399$) were observed throughout the 35-d study. There was no evidence for differences for the pigs consuming diets with added Monomix, other than decreased feed intake ($P = 0.002$) and average daily gain (ADG; $P = 0.012$) from d 0 to 7, resulting in decreased body weight (BW) ($P = 0.015$) at d 7. From d 0 to 7 and 7 to 18, pigs fed diets with added ZnO had increased ADG ($P < 0.001$), average daily feed intake (ADFI), and BW, and improved feed efficiency (F/G). Overall from d 0 to 35, pigs fed diets with added ZnO in phases 1 and 2 had increased ($P < 0.05$) ADG, ADFI, and d 35 BW, with no evidence for differences in performance in pigs fed diets with Monomix. In summary, the addition of Monomix did not improve pig performance, whereas pharmacological levels of ZnO improved ADG and ADFI similarly to previous studies.

Introduction

Pharmacological levels of ZnO have been widely adopted in nursery swine diets for the ability to reduce post-weaning diarrhea and improve growth performance. Recently, the inclusion of high ZnO levels in swine diets has been banned in EU countries due to environmental concerns and antibiotic resistance risk. In recent years, short

[1] Appreciation is expressed to Quality Technology International, Inc. (Elgin, IL) for their partial financial support of this trial.
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and medium chain fatty acids along with their analogous monoglycerides have been shown to have antimicrobial effects on Gram-positive bacteria.[4] It has been suggested that alpha-monoglycerides have a stronger antibacterial and anti-inflammatory effect compared to free fatty acids. Monomix (Quality Technology International, Inc., Elgin, IL), a blended product containing the alpha-monoglycerides of C3, C4, C8, and C10, is thought to combine the antibacterial effect of short and medium chain fatty acids on gram-negative and gram-positive bacteria, respectively. European field studies suggest Monomix can elicit beneficial growth performance responses similar to pharmacological levels of ZnO; however, we are unaware of any controlled research studies with Monomix conducted in the United States. Therefore, the objective of this experiment was to determine the effect of adding Monomix alone and in combination with pharmacological levels of ZnO on growth performance of nursery pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State University Segregated Early Weaning Facility in Manhattan, KS. The facility has two identical barns that are completely enclosed, environmentally controlled, and mechanically ventilated. Treatments were equally represented in each barn. Each pen contained a 4-hole, dry self-feeder and a cup waterer to provide *ad libitum* access to feed and water. Pens (4 × 4 ft) had metal tri-bar floors and allowed approximately 2.7 ft^2/pig.

Following arrival to the research facility, pigs (DNA; 200 × 400; initial BW = 13.0 lb) were used in a 35-d study with 5 pigs per pen and 18 pens per treatment. Upon arrival to the nursery research facility, pigs were randomly assigned to pens and then pens were allotted to 1 of 4 dietary treatments. Dietary treatments were arranged in a 2 × 2 factorial with main effects of added ZnO (0 vs. 3,000 ppm and 2,000 ppm in phases 1 and 2 diets, respectively) and Monomix (Quality Technology International, Inc., Elgin, IL; 0 vs. 0.4% in phases 1, 2, and 3). Treatment diets were offered in three dietary phases (phase 1 fed from d 0 to 7, phase 2 from d 7 to 18, and phase 3 from 18 to 35 post-weaning) and were formulated to meet or exceed NRC[5] requirement estimates (Table 1). The first phase was fed in pellet form and the following phases were fed as meal. The Monomix and ZnO were included at the expense of corn in the control diet to form the treatments, and diets were formulated to be isocaloric (NE basis) by adjusting soybean oil based on ingredient loading values according to NRC[5] and a Monomix NE of 4,300 kcal/kg as suggested by the supplier. Diets were manufactured at the O.H. Kruse Feed Technology Innovation Center at Kansas State University, Manhattan, KS. Pig weight and feed disappearance were measured on d 0, 7, 18, 25, and 35 of the trial to determine ADG, ADFI, and F/G.

Complete diet samples were taken during the manufacturing of each phase and were stored at -20°C until they were homogenized, subsampled, and submitted for analysis of dry matter and zinc (Ward Laboratories, Inc., Kearney, NE).

[4] Bergsson, G., J. Arnfinnsson, O. Steingrímsson, and H. Thormar. 2001. Killing of gram-positive cocci by fatty acids and monoglycerides. APMIS. 109:670-8. doi:10.1034/j.1600-0463.2001.d01-131.x.

[5] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

Data were analyzed as a completely randomized design using the GLIMMIX procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Barn was included in the model as a random effect. The main effects of Monomix and ZnO, as well as their interactions, were tested. Differences between treatments were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

The chemical analyses of the experimental diets were similar to those calculated from diet formulation in respect of formulated zinc concentration (Table 2).

There were no ZnO × Monomix interactions observed throughout the 35-d study (Tables 5 and 6). For the main effects of Monomix, from d 0 to 7, pigs fed 0.4% Monomix had decreased ($P = 0.002$) ADFI and ADG, resulting in decreased BW on d 7 with no evidence of difference in F/G. There was no evidence for differences in pig performance when fed diets containing Monomix after phase 1 for the duration of the trial.

For the main effect of added ZnO, from d 0 to 7 and 7 to 18, pigs fed diets with pharmacological levels of ZnO had increased ADG ($P < 0.001$), ADFI, BW, and improved F/G. From d 18 to 35, once the pharmacological Zn was removed from these diets, growth and feed efficiency of pigs did not differ among treatments.

Overall, from d 0 to 35, pigs fed diets with added ZnO in phases 1 and 2 had increased ADG ($P = 0.029$), ADFI ($P = 0.047$), and d 35 BW ($P = 0.025$) with no evidence for difference observed for F/G. The addition of Monomix in diets resulted in no evidence for difference in overall ADG, ADFI, or F/G.

In summary, the addition of pharmacological levels of ZnO improved growth performance similarly to results of previous studies.[6,7] In our study, the addition of Monomix did not elicit any beneficial effects on growth performance or feed efficiency of pigs, regardless of whether high levels of ZnO were in the diet or not. Consequently, this study suggests that Monomix is not a suitable replacement for pharmacological levels of ZnO fed to weanling pigs.

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[6] Case, C.L., and M.S. Carlson. 2002. Effect of feeding organic and inorganic sources of additional zinc on growth performance and zinc balance in nursery pigs. J. Anim. Sci. 80:1917-1924. https://doi.org/10.2527/2002.8071917x.

[7] Smith, J.W., M.D. Tokach, R.D. Goodband, J.L. Nelssen, and B.T. Richert. 1997. Effects of the interrelationship between zinc oxide and copper sulfate on growth performance of early-weaned pigs. J. Anim. Sci. 75:1861-1866. https://doi.org/10.2527/1997.7571861x.

Table 1. Phase 1 diet composition (as-fed basis)[1]

		No Zinc oxide		Zinc oxide[3]	
Ingredient, %	Monomix:[2]	0%	0.4%	0%	0.4%
Corn		45.01	44.68	44.31	44.04
Soybean meal, 46.5% CP		19.39	19.41	19.44	19.46
Fish meal		4.50	4.50	4.50	4.50
Whey powder		25.0	25.0	25.0	25.0
HP 300[4]		2.50	2.50	2.50	2.50
Soybean oil		1.00	0.90	1.25	1.10
Calcium carbonate		0.40	0.40	0.40	0.40
Monocalcium phosphate, 21%		0.40	0.40	0.40	0.40
Salt		0.30	0.30	0.30	0.30
L-Lysine HCl		0.43	0.43	0.43	0.43
DL-Methionine		0.21	0.22	0.22	0.22
L-Threonine		0.19	0.19	0.19	0.19
L-Tryptophan		0.03	0.03	0.03	0.03
L-Valine		0.15	0.15	0.15	0.15
Trace mineral		0.15	0.15	0.15	0.15
Vitamin premix		0.25	0.25	0.25	0.25
Choline chloride 60%		0.04	0.04	0.04	0.04
Phytase[5]		0.02	0.02	0.02	0.02
Vitamin E, 20,000 IU		0.05	0.05	0.05	0.05
Zinc oxide		---	---	0.40	0.40
Monomix		---	0.40	---	0.40
Total		100	100	100	100

continued

Table 1. Phase 1 diet composition (as-fed basis)[1]

		No Zinc oxide		Zinc oxide[3]	
Ingredient, %	Monomix:[2]	0%	0.4%	0%	0.4%
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine		1.40	1.40	1.40	1.40
Isoleucine:lysine		56	56	56	56
Leucine:lysine		110	109	109	109
Methionine:lysine		37	37	37	37
Methionine and cysteine:lysine		57	57	57	57
Threonine:lysine		63	63	63	63
Tryptophan:lysine		18.5	18.5	18.5	18.5
Valine:lysine		70	70	70	70
Total lysine, %		1.53	1.53	1.53	1.53
ME,[6] kcal/lb		1,543	1,534	1,543	1,533
NE, kcal/lb		1,161	1,161	1,161	1,161
SID lysine:NE, g/Mcal		5.46	5.45	5.45	5.46
Crude protein, %		20.9	20.9	20.9	20.8
Calcium, %		0.72	0.72	0.72	0.72
Phosphorus, %		0.67	0.66	0.66	0.66
Available phosphorus, %		0.52	0.52	0.52	0.52
STTD P,[7] %		0.54	0.54	0.54	0.54

[1]Phase 1 diets were fed from approximately 13 to 14 lb.
[2]Monomix (Quality Technology International, Inc., Elgin, IL) was included in the diet at 0 or 0.4% from d 0 to 35.
[3]Zinc oxide was included in the diet to provide 3,000 ppm of Zn.
[4]HP 300 (Hamlet Protein, Findlay, OH).
[5]HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided an estimated release of 0.10% STTD P.
[6]ME = metabolizable energy. NE = net energy.
[7]Standardized total tract digestible phosphorus.

Table 2. Phase 2 diet composition (as-fed basis)[1]

		No Zinc oxide		Zinc oxide[3]	
Ingredient, %	Monomix:[2]	0%	0.4%	0%	0.4%
Corn		55.60	55.30	55.15	54.90
Soybean meal, 46.5% CP		24.80	24.80	24.80	24.85
Whey powder		10.0	10.0	10.0	10.0
HP 300[4]		5.0	5.0	5.0	5.0
Soybean oil		1.0	0.85	1.15	1.0
Calcium carbonate		0.80	0.80	0.80	0.80
Monocalcium phosphate, 21%		0.90	0.90	0.90	0.90
Salt		0.55	0.55	0.55	0.55
L-Lysine HCl		0.45	0.45	0.45	0.45
DL-Methionine		0.21	0.21	0.21	0.21
L-Threonine		0.19	0.19	0.19	0.19
L-Tryptophan		0.02	0.02	0.02	0.02
L-Valine		0.10	0.10	0.10	0.10
Trace mineral		0.15	0.15	0.15	0.15
Vitamin premix		0.25	0.25	0.25	0.25
Phytase[5]		0.02	0.02	0.02	0.02
Zinc oxide		---	---	0.26	0.26
Monomix		---	0.40	---	0.40
Total		100	100	100	100

continued

Table 2. Phase 2 diet composition (as-fed basis)[1]

		No Zinc oxide		Zinc oxide[3]	
Ingredient, %	Monomix:[2]	0%	0.4%	0%	0.4%
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine		1.35	1.35	1.35	1.35
Isoleucine:lysine		58	58	58	58
Leucine:lysine		115	115	115	115
Methionine:lysine		36	36	36	36
Methionine and cysteine:lysine		57	57	57	57
Threonine:lysine		63	63	63	63
Tryptophan:lysine		18.5	18.5	18.5	18.5
Valine:lysine		69	69	69	69
Total lysine, %		1.49	1.49	1.49	1.49
ME,[6] kcal/lb		1,521	1,512	1,521	1,511
NE, kcal/lb		1,133	1,133	1,133	1,133
SID lysine:NE, g/Mcal		5.41	5.41	5.40	5.41
Crude protein, %		21.1	21.1	21.1	21.1
Calcium, %		0.70	0.70	0.70	0.70
Phosphorus, %		0.62	0.62	0.62	0.62
Available phosphorus, %		0.43	0.43	0.43	0.43
STTD P,[7] %		0.47	0.47	0.47	0.47

[1]Phase 2 diets were fed from approximately 14 to 22 lb.
[2]Monomix (Quality Technology International, Inc., Elgin, IL) was included in the diet at 0 or 0.4% from d 0 to 35.
[3]Zinc oxide was included in the diet to provide 2,000 ppm of Zn.
[4]HP 300 (Hamlet Protein, Findlay, OH).
[5]HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided an estimated release of 0.10% STTD P.
[6]ME = metabolizable energy. NE = net energy.
[7]Standardized total tract digestible phosphorus.

Table 3. Phase 3 diet composition (as-fed basis)[1]

		No Zinc oxide[3]	
Ingredient, %	Monomix:[2]	0%	0.4%
Corn		60.70	60.40
Soybean meal, 46.5% CP		34.60	34.65
Soybean oil		1.0	0.88
Calcium carbonate		0.85	0.85
Monocalcium phosphate, 21%		1.15	1.15
Salt		0.60	0.60
L-Lysine HCl		0.35	0.35
DL-Methionine		0.15	0.15
L-Threonine		0.14	0.14
L-Tryptophan		0.004	0.004
L-Valine		0.04	0.04
Trace mineral		0.15	0.15
Vitamin premix		0.25	0.25
Phytase[4]		0.02	0.02
Zinc oxide		---	---
Monomix		---	0.40
Total		100	100

continued

Table 3. Phase 3 diet composition (as-fed basis)[1]

		No Zinc oxide[3]	
Ingredient, %	Monomix:[2]	0%	0.4%
Calculated analysis			
Standardized ileal digestible (SID) amino acids, %			
Lysine		1.30	1.30
Isoleucine:lysine		61	61
Leucine:lysine		124	124
Methionine:lysine		34	34
Methionine and cysteine:lysine		57	57
Threonine:lysine		63	63
Tryptophan:lysine		18.5	18.5
Valine:lysine		69	69
Total lysine, %		1.45	1.45
ME,[5] kcal/lb		1,505	1,496
NE, kcal/lb		1,108	1,108
SID lysine:NE, g/Mcal		5.32	5.32
Crude protein, %		22.1	22.1
Calcium, %		0.72	0.72
Phosphorus, %		0.65	0.65
Available phosphorus, %		0.42	0.42
STTD P,[6] %		0.47	0.47

[1]Phase 3 diets were fed from approximately 22 to 42 lb.
[2]Monomix (Quality Technology International, Inc., Elgin, IL) was included in the diet at 0 or 0.4% from d 0 to 35.
[3]Zinc oxide was not included in the phase 3 diet.
[4]HP 300 (Hamlet Protein, Findlay, OH).
[5]ME = metabolizable energy. NE = net energy.
[6]Standardized total tract digestible phosphorus. HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided an estimated release of 0.10% STTD P.

Table 4. Analyzed diet composition (as-fed basis)[1]

		No Zinc oxide		Zinc oxide[3]	
Analyzed composition, %[4]	Monomix:[2]	0%	0.4%	0%	0.4%
Phase 1					
Dry matter		91.01	90.70	91.06	91.0
Zinc		110.07	165.5	2,950.03	2,911.13
Phase 2					
Dry matter		89.88	90.03	88.95	89.09
Zinc		137.8	187.23	1,617.77	2,066.70
Phase 3					
Dry matter		87.49	87.67	87.87	87.81
Zinc		168.67	158.6	119.87	144.5

[1]Diets were fed in 3 phases from d 0 to 7, 7 to 18, and 18 to 35 for phases 1, 2, and 3, respectively.
[2]Monomix (Quality Technology International, Inc., Elgin, IL) was included in the diet at 0 or 0.4% from d 0 to 35.
[3]Zinc oxide was included in the diet at 3,000 ppm of Zn from d 0 to 7; 2,000 ppm of Zn from d 7 to 18; and no additional Zn other than that from the TM premix from d 18 to 35.
[4]Complete diet samples were taken at manufacture. Samples were stored at -20°C until they were homogenized, subsampled, and submitted to Ward Laboratories, Inc. (Kearney, NE) for proximate analysis.

Table 5. Interactive effects of added Monomix and/or pharmacological levels of ZnO on nursery pig performance[1]

		No Zinc oxide		Zinc oxide[3]			Probability, *P*=		
Item	Monomix:[2]	0%	0.4%	0%	0.4%	SEM	Monomix × ZnO	Monomix	ZnO
Weight, lb									
d 0		13.1	13.0	13.0	13.0	0.05	0.375	0.636	0.408
d 7		14.3	14.1	14.7	14.4	0.11	0.476	0.015	<0.001
d 18		21.2	21.7	23.4	23.2	0.53	0.300	0.676	<0.0001
d 35		41.3	42.2	43.4	43.2	1.14	0.369	0.587	0.025
d 0 to 7									
ADG,[4] lb		0.17	0.15	0.24	0.20	0.020	0.424	0.012	<0.001
ADFI, lb		0.22	0.20	0.26	0.22	0.019	0.222	0.002	0.005
F/G		1.43	1.56	1.11	1.21	0.135	0.878	0.336	0.006
d 7 to 18									
ADG, lb		0.45	0.47	0.58	0.56	0.033	0.369	0.890	<0.0001
ADFI, lb		0.56	0.58	0.69	0.66	0.046	0.301	0.781	<0.0001
F/G		1.25	1.23	1.19	1.18	0.020	0.865	0.463	0.005
d 18 to 35									
ADG, lb		1.13	1.16	1.17	1.16	0.036	0.497	0.684	0.573
ADFI, lb		1.61	1.63	1.66	1.65	0.075	0.730	0.984	0.357
F/G		1.42	1.40	1.42	1.42	0.016	0.494	0.369	0.394
d 0 to 35									
ADG, lb		0.81	0.82	0.87	0.85	0.036	0.399	0.922	0.029
ADFI, lb		1.13	1.13	1.19	1.17	0.060	0.560	0.667	0.047
F/G		1.40	1.37	1.38	1.37	0.017	0.483	0.189	0.506

[1]A total of 354 pigs (average initial body weight = 13.0 lb) were used in a 35-d growth study with 5 pigs per pen and 18 pens per treatment.
[2]Monomix (Quality Technology International, Inc., Elgin, IL) was included in the diet at 0 or 0.4% from d 0 to 35.
[3]Zinc oxide was included in the diet to provide 3,000 ppm of Zn from d 0 to 7; 2,000 ppm of Zn from d 7 to 18; and no additional Zn other than that from the TM premix from d 18 to 35.
[4]ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency.

Table 6. Main effects of added Monomix and/or pharmacological levels of ZnO on nursery pig growth performance[1]

	Monomix				Zinc oxide			
Item	0%	0.4%[2]	SEM	*P*-value	No	Yes[3]	SEM	*P*-value
Weight, lb								
d 0	13.0	13.0	0.05	0.636	13.0	13.0	0.05	0.408
d 7	14.5	14.2	0.08	0.015	14.2	14.5	0.08	<0.001
d 18	22.3	22.5	0.46	0.676	21.5	23.3	0.46	<0.0001
d 35	42.3	42.7	1.04	0.587	41.8	43.3	1.04	0.025
d 0 to 7								
ADG,[4] lb	0.20	0.17	0.018	0.012	0.16	0.21	0.018	<0.001
ADFI, lb	0.24	0.21	0.018	0.002	0.21	0.24	0.018	0.005
F/G	1.27	1.38	0.106	0.336	1.49	1.16	0.106	0.006
d 7 to 18								
ADG, lb	0.52	0.52	0.030	0.890	0.46	0.57	0.030	<0.0001
ADFI, lb	0.62	0.62	0.043	0.781	0.57	0.67	0.043	<0.0001
F/G	1.22	1.20	0.015	0.463	1.24	1.18	0.015	0.005
d 18 to 35								
ADG, lb	1.15	1.16	0.040	0.684	1.15	1.16	0.040	0.573
ADFI, lb	1.64	1.64	0.071	0.984	1.62	1.65	0.071	0.357
F/G	1.42	1.41	0.013	0.369	1.41	1.42	0.013	0.394
d 0 to 35								
ADG, lb	0.84	0.84	0.033	0.922	0.82	0.86	0.033	0.029
ADFI, lb	1.16	1.15	0.057	0.667	1.13	1.18	0.057	0.047
F/G	1.39	1.37	0.015	0.189	1.39	1.38	0.015	0.506

[1]A total of 354 pigs (average initial body weight = 13.0 lb) were used in a 35-d growth study with 5 pigs per pen and 36 pens per treatment.
[2]Monomix (Quality Technology International, Inc., Elgin, IL) was included in the diet at 0 or 0.4% from d 0 to 35.
[3]Zinc oxide was included in the diet to provide 3,000 ppm Zn from d 0 to 7; 2,000 ppm Zn from d 7 to 18; and no additional Zn other than that from the TM premix from d 18 to 35.
[4]ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency.